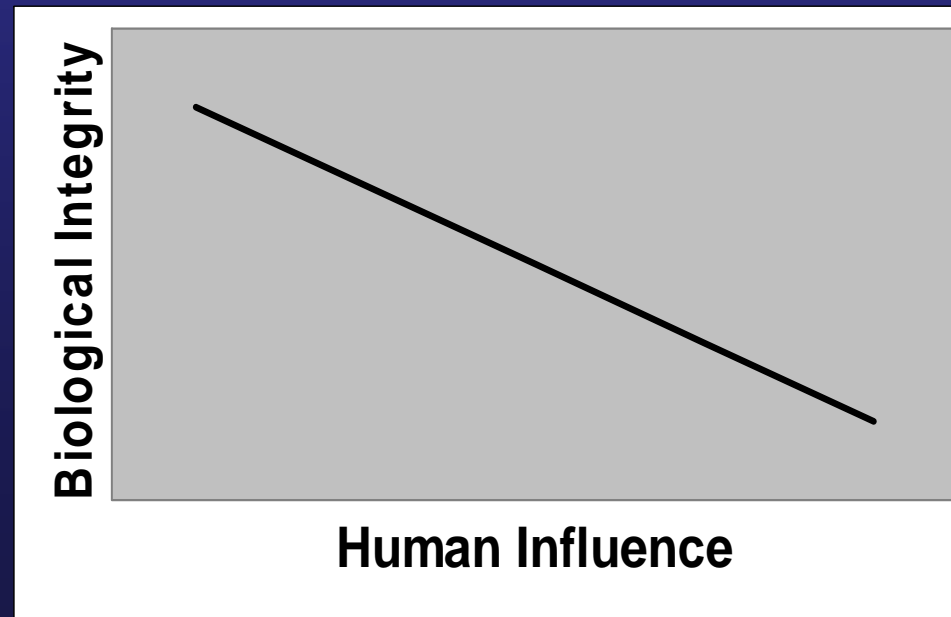**North Cascades
Index of Biotic Integrity**
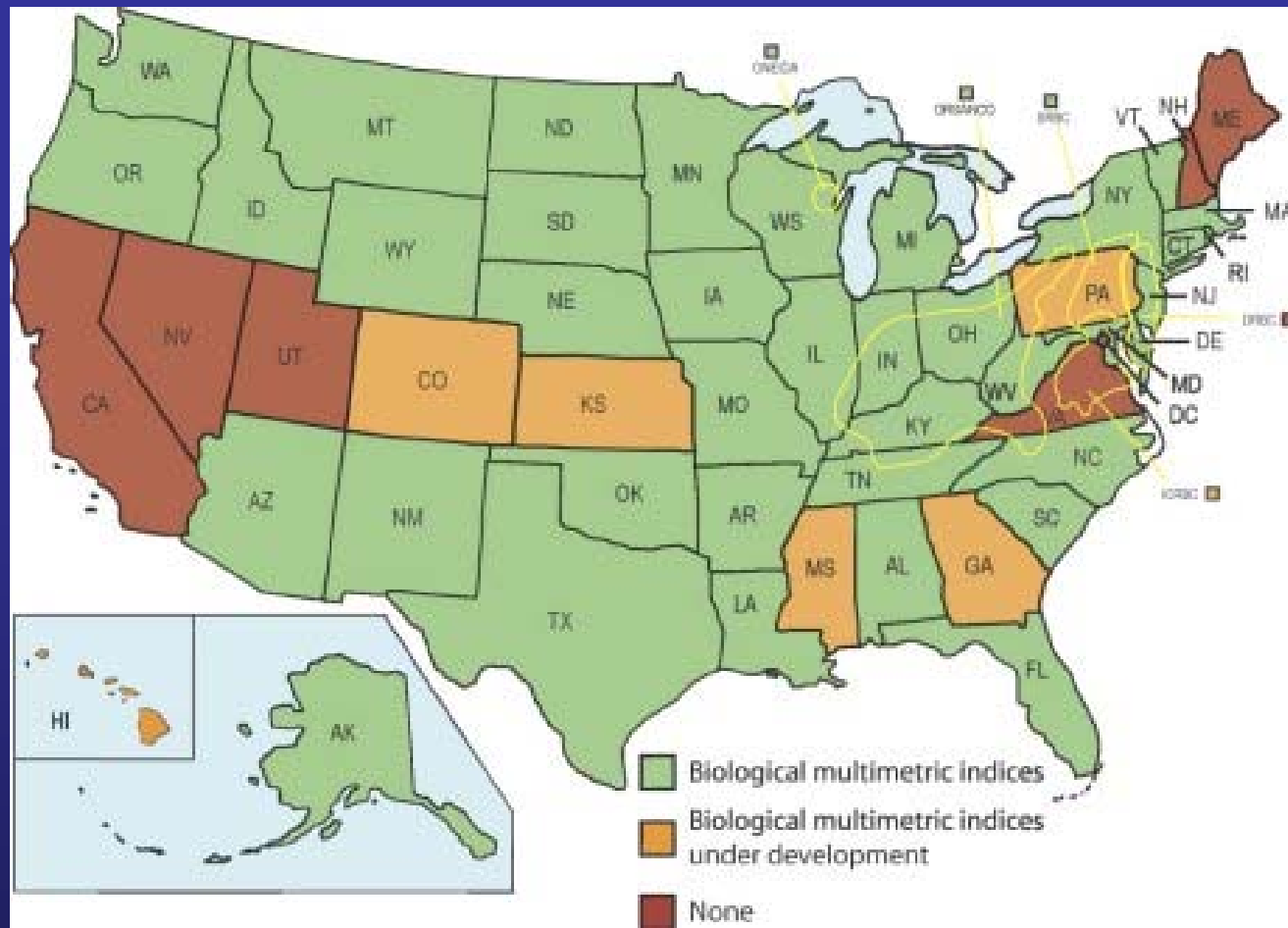
Biological Integrity

The capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region. (Karr & Dudley 1981)

Why measure biological integrity?

- Integrates physical and chemical conditions over time.

- Ultimately we are interested in the biology of aquatic systems.

- Clean Water Act (101(a))

Biological multimetric indices

Biological multimetric indices under development

None

Drunella doddsi

The Xerces Society
www.xerces.org

Biological Integrity ≈ Pattern

Macroinvertebrates in the North Cascades

- Represent 237 Taxa

- Sensitive to Disturbance

- Not Highly Mobile (immatures)

- Many are Long Lived

PROJECT OBJECTIVES

- Develop the framework and standards necessary for implementation of a BMI biomonitoring program for streams within NOCA and adjacent USFS lands.

- Evaluate and compare the sensitivity of both multivariate and multimetric approaches in detecting human disturbance.

Framework and Standards

Components:

- **Stratification of potential sample sites**

- **Determine reference site criteria**

- **Assign sample sites to appropriate classes**

- **Field sampling and laboratory procedures**

- **QA/QC and BMI reference collections**

- **Data analysis procedures (multivariate and multimetric approaches)**

- **Data management procedures**
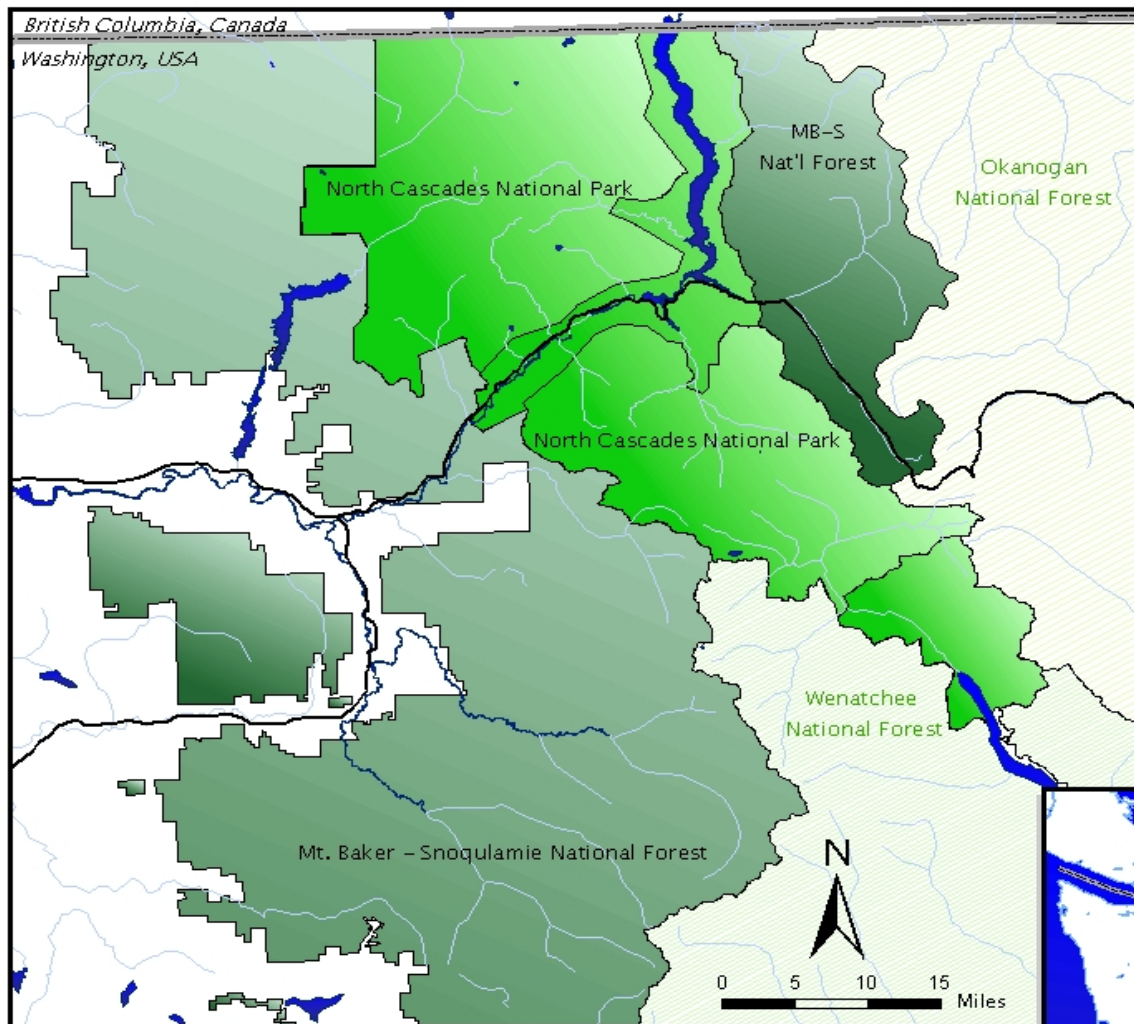
North Cascades
National Park
Service Complex
and
Mt. Baker District,
Mt. Baker–Snoqualmie
National Forest

Major Watersheds in Study Area
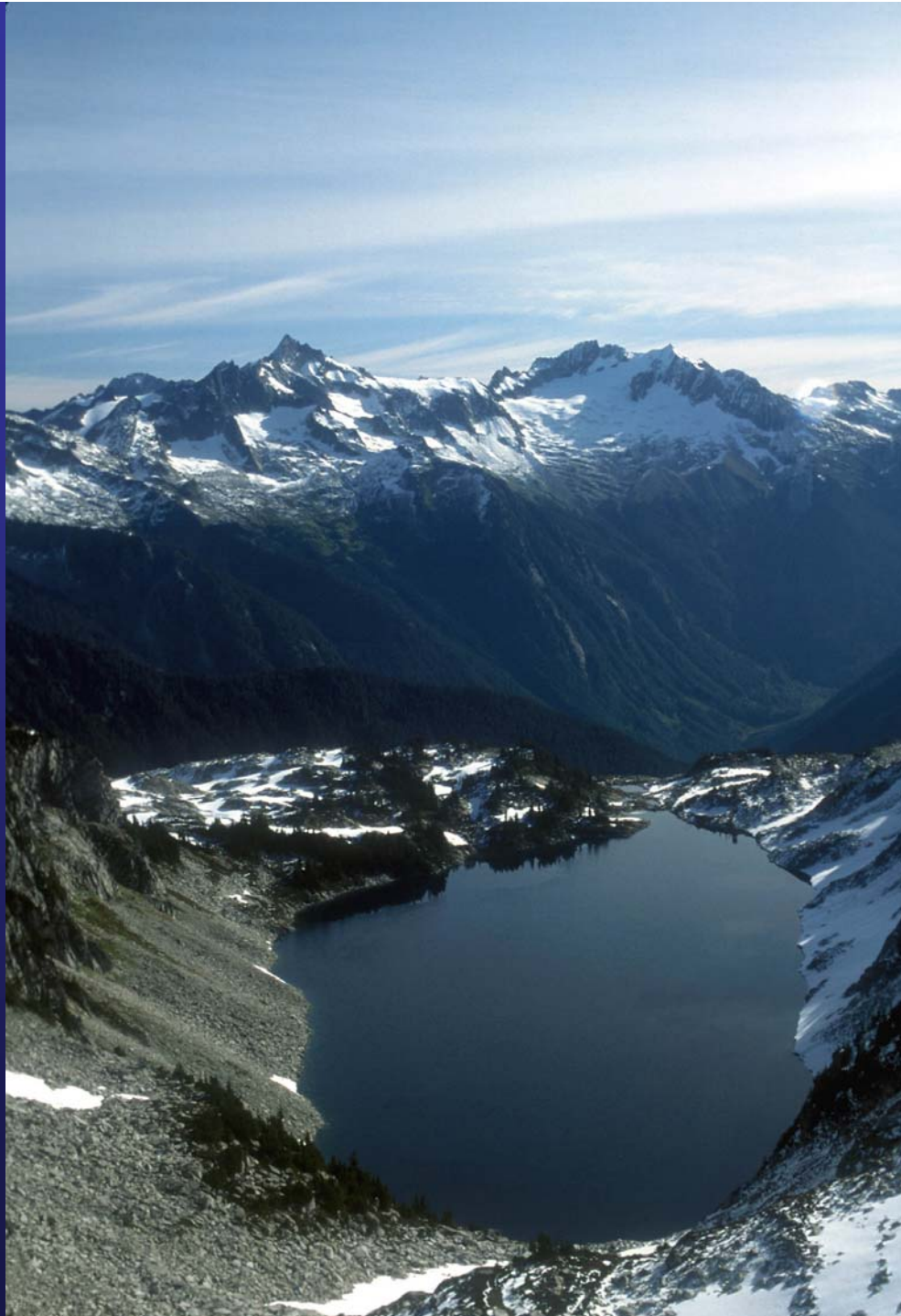
Stratification of Sample Sites

- Elevation

- Upstream catchment area

- Stream order

- Gradient

- Latitude - longitude

- Distance from source

- Precipitation Zone

- Rain-on-snow area

- Glacial area

Sample Site Stratification
Watershed Types defined as follows:

Watershed Type	Elevation (m)	Upstr. Catch. Area (km²)
Ia	< 900	< 16
Ib	> 900	< 16
IIa	< 900	16-50
IIb	> 900	16-50
III	< 900	> 50

Reach elevations range 30 m to 1560 m with most of the sites at elevations less than 900m (89%). Reaches > 900m elevation are represented by a total of 19 (11%) sample sites.

Framework and Standards

Components:

- Stratification of potential sample sites

- **Determine reference site criteria**

- Assign sample sites to appropriate classes

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Reference Site Criteria

- **Recreational Use (type and density)**

- **Agriculture**

- **Urban Development**

- **Hydraulic Modifications**

- **Logging**

- **Road Density**

- **Mining**

Scoring Criteria for Logging

1. 0% of watershed logged within the last 40 years.   (0)

2. Up to 10% of watershed logged within the last 40 years.   (1-9)

3. 10 to 19% of watershed logged within the last 40 years.   (10-19)

4. 4. 20 to 29% of watershed logged within the last 40 years.   (20-29)

5. 30% or greater logged with in the last 40 years.   (30-39)

Logging

Road Failure

Hydraulic Disturbances

Recreation Scoring Criteria

1. Remote-difficult travel, mostly cross country to few trails, primarily overnight use. No established backcountry camp sites.   (0-3)

2. Mixture of off-trail and moderate trail development with use limited to foot traffic or horses, overnight use only. Established backcountry camping sites.   (4-6)

3. Same use a in No. 2 with inclusion of front country trails (within three miles of trail head) and moderate road connections.   (7-10)

4. High road density providing for areas of dispersed recreation developed drive-in campgrounds, moderate to high trail development multiple trailheads, moderate or greater ORV use.   (11-15)
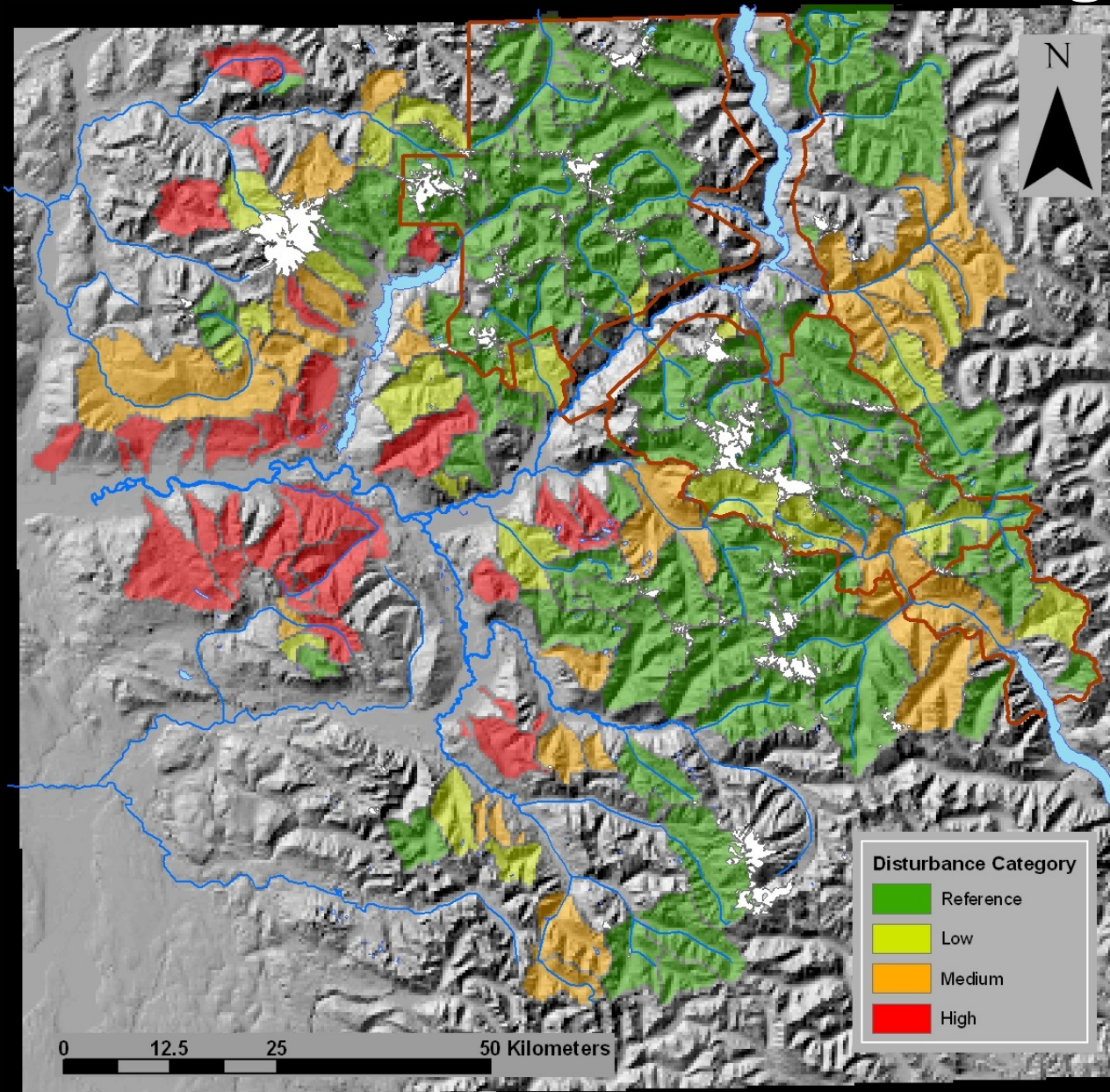
Recreational Use

Distribution of Disturbance Categories

Disturbance Category
- Reference
- Low
- Medium
- High

0   12.5   25   50 Kilometers

Disturbance Scores for Selected Watersheds

Name	Logging Score	Road Density Score	Hydraulic Mod. Score	Mining Score	Rec. Score	Ag. Score	Urban Score	Fire Score	Total Disturbance Score
Chilliwack	0	0	0	2	6	0	0	7	15
Bear	0	0	0	0	4	0	0	2	6
Finney	39	34	10	1	7	0	6	1	98
Muddy	39	26	15	10	12	15	10	0	127

Lower Chilliwack River

Lower Finney Creek

Bear Creek

Muddy Creek

Final Reach Sample Size by Watershed Type/Disturbance Score

Watershed Type	Total Sample Size	Disturbance Category (n)				
		1	2	3	4	5
IA	31	9	4	6	7	5
IB	7	6	1	0	0	0
IIA	54	21	13	4	10	6
IIB	7	5	2	0	0	0
III	59	23	20	8	5	3
Total	158	64	40	18	22	14

Disturbance Category	Score
1	0 - 15
2	16 - 35
3	36 - 50
4	51 - 80
5	81 - 127

Sample Locations

Physical and Chemical Attributes

	Elevation (m)	Area (km^2)	% Gradient	Bankful Width (m)	Conductivity (µS)
Minimum	24	0.8	0.5	2.2	8.4
Maximum	1597	252	20	86.9	190
Median	510	33	3	15.5	34.7

Sample Collection

- **Sampling period = August through September**

- **Sample reaches = 20 to 40 channel widths**

- **Physical measurements = bankful width and depth, LWD, habitat types, substrate, riparian vegetation, disturbances, canopy cover, conductivity and temperature**

- **Biological Sampling = 3 to 5, 0.19 m² sub-samples**

Laboratory Procedures

- Samples sorted in the lab – all individuals sorted and identified to lowest taxonomic level usually genus and species.

- Data pooled for analyses and random sample of 500 individuals selected for each reach.

Framework and Standards

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- **Data analysis procedures (multivariate and multimetric approaches)**

- Data management procedures

Multimetric Index Development

- Identification and definition of
  candidate metrics
- Metric Selection
- Metric Calibration
- Compilation of the NCIBI
- Assessment of NCIBI

Multimetric Index Development

- **Identification and definition of candidate metrics**
- Metric Selection
- Metric Calibration
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- Assessment of NCIBI

Identification and definition of candidate metrics

Candidate metrics were identified and defined from regional labs and published reports.

Environmental Protection Agency

Washington DOE

Oregon DEQ

Idaho DEQ

Montana DEQ

Wyoming DEQ

Aquatic Biology Associates, Inc.

EcoAnalysts, Inc.

Identification and definition of candidate metrics

Candidate metrics categorized according to:

Abundance (n = 2)

Dominance (n = 10)

Richness (n = 14)

Composition (n = 35)

Functional Feeding Group (n = 23)

Habit (n = 3)

Diversity Indices (n = 5)

Biotic Indices (n = 7)

Voltanism (n = 4)

Indicator Assemblages (n = 18)

Composition Metrics	Predicted Response to Stress	Agency and Lab						
		ABA	EcoA	EPA	WA	ID	OR	MT
% EPT	-	X	X	X	X	X		X
% Ephemeroptera	-	X	X	X	X	X		X
% Plecoptera	-	X	X	X		X		X
% Trichoptera	-	X	X			X		
% Coleoptera	unclear	X	X					
% Diptera	+	X	X	X		X		
% Diptera non-chironomidae	+					X		
% Hemiptera	unclear		X					
% Lepidoptera	unclear		X					
% Megaloptera	unclear		X					
% Odonata	+	X						
% Oligochaeta	+/-	X		X				
% Planaria + Amphipoda	unclear		X					
% Baetidae	+	X						X
% Brachycentridae	+/-	X						
% Chironomidae	+	X	X	X	X			X
% Elmidae	-		X			X		
% Ephemerellidae	+/-	X						
% Glossosomatidae	-							
% Heptageniidae	unclear							
% Hydropsychidae	+	X				X		X
%Lepidostomatidae	unclear							
%Nemouridae	unclear							
% Peltoperlidae	unclear							
% Perlidae		X						
% Perlodidae	unclear							
% Philopotamidae	-							
% Psychomyiidae	-							
% Pteronarcyidae	-	X						
%Rhyacophilidae	unclear							
% Simuliidae	+	X						
% Non-insect	+		X	X		X		
EPT / Chironomidae	-		X					
Hydropsychidae / Trichoptera	+		X	X				
Baetidae / Ephemeroptera	+		X					

n = 121

Multimetric Index Development

- Identification and definition of candidate metrics
- **Metric Selection**
- Metric Calibration
- Compilation of the NCIBI
- Assessment of NCIBI

Metric Selection Criteria

- Range of values
- Percent of values greater than zero
- Respond as predicted
- Discrimination Efficiency
- Redundancy

Metric Selection Criteria

- **Range of values**
- **Percent of values greater than zero**
- Respond as predicted
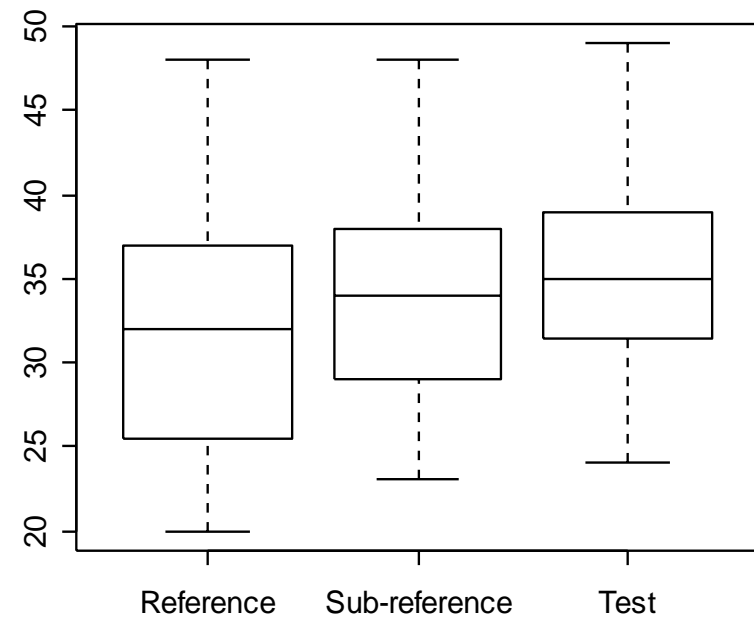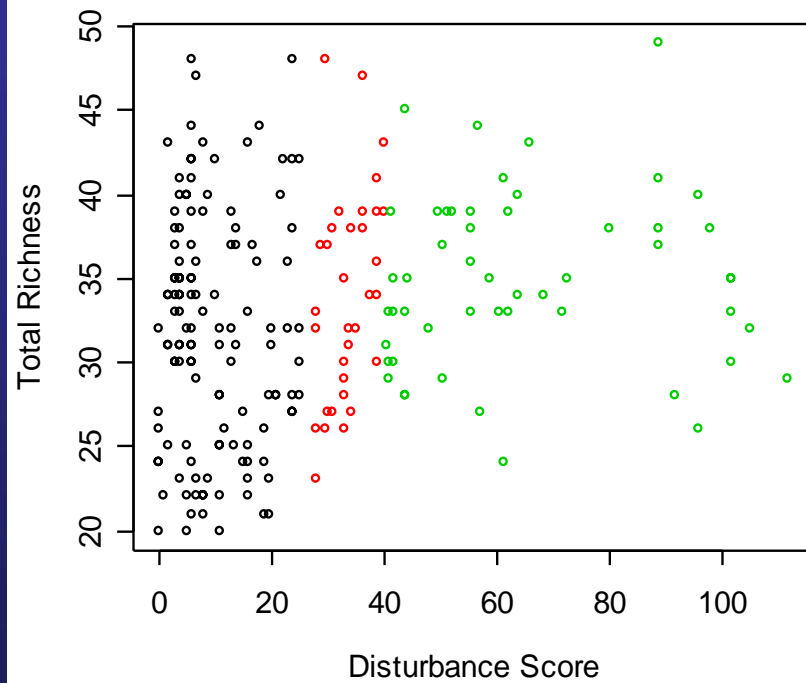- Discrimination Efficiency
- Redundancy

| Composition Metrics	Min.	Max.	Median	% Values >0
% EPT	42.00	99.20	87.90	100
% Ephemeroptera	15.60	91.00	64.50	100
% Plecoptera	2.00	46.67	10.10	100
% Trichoptera	0.20	50.60	5.80	100
% Coleoptera	0.00	1.40	0.00	18
% Diptera	0.20	28.60	5.40	100
% Diptera non-chironomidae	0	15.4	1.4	97
% Hemiptera	0	0	0	0
% Lepidoptera	0	0	0	0
% Megaloptera	0	0	0	0
% Odonata	0	0	0	0
% Oligochaeta	0.00	36.00	2.00	85
% Planaria + Amphipoda	0	0	0	0
%Baetidae	0.40	48.40	12.90	100
%Brachycentridae	0.00	2.40	0.00	17
%Chironomidae	0.00	27.20	3.63	97
%Elmidae	0.00	1.40	0.00	14
%Ephemerellidae	1.60	48.20	8.30	100
%Glossosomatidae	0.00	41.60	0.20	54
%Heptageniidae	4.80	68.40	29.40	100
%Hydropsychidae	0.00	7.60	0.90	83
%Lepidostomatidae	0.00	2.20	0.00	18
%Nemouridae	0.00	24.80	2.40	97
%Peltoperlidae	0.00	11.40	0.00	44
%Perlidae	0.00	5.80	0.00	39
%Perlodidae	0.00	8.40	0.80	86
% Philopotamidae	0.00	2.80	0.00	7
%Psychomyiidae	0.00	0.20	0.00	1
% Pteronarcyidae	0.00	2.40	0.00	10
%Rhyacophilidae	0.00	7.00	1.60	96
%Simuliidae	0.00	6.80	0.20	60
% Non-insect	0.00	37.00	4.10	97
EPT /Chironomidae	1.83	496.00	24.80	97
Hydropsychidae / Trichoptera	0.00	1.00	0.15	83
Baetidae / Ephemeroptera	0.01	0.69	0.23	100

n = 73

Metric Selection Criteria

- Range of values
- Percent of values greater than zero
- **Respond as predicted**
- Discrimination Efficiency
- Redundancy

Total Richness Metric

Biotic Condition Index
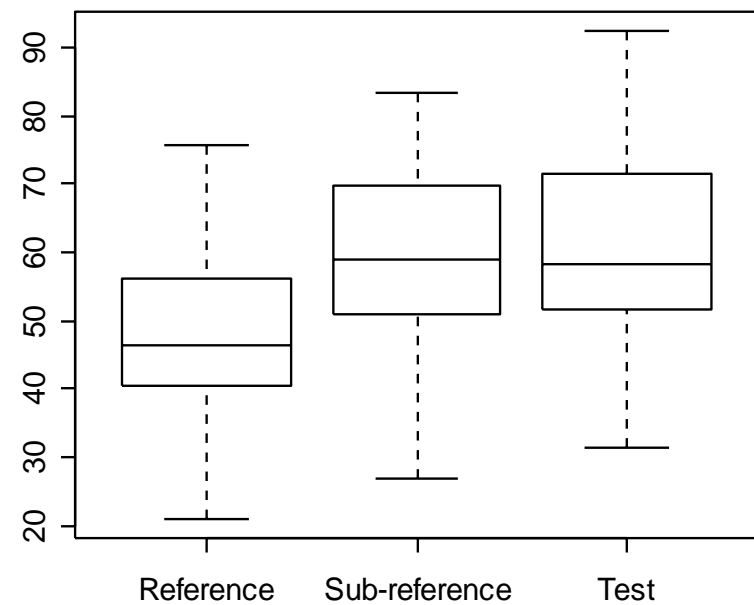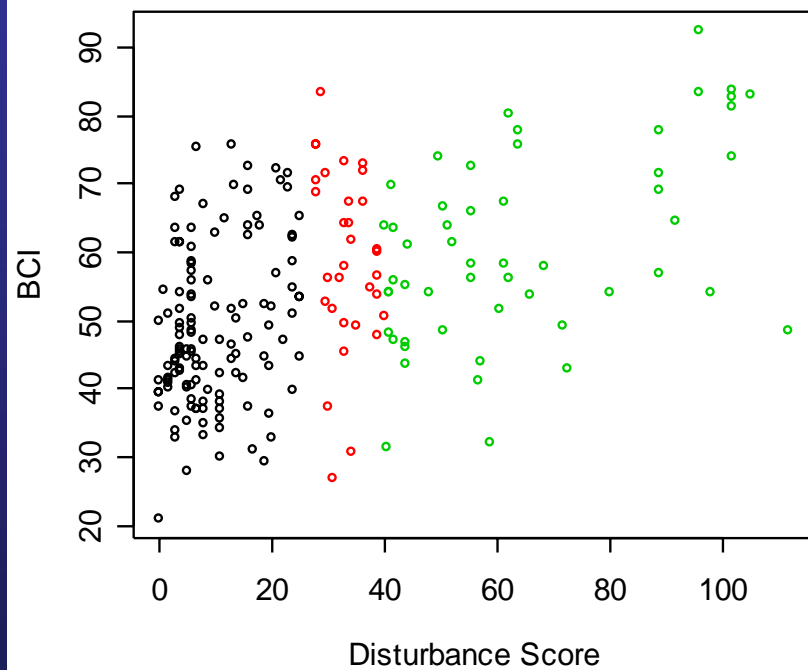
Metric Selection Criteria

- Range of values
- Percent of values greater than zero
- Respond as predicted
- **Discrimination Efficiency**
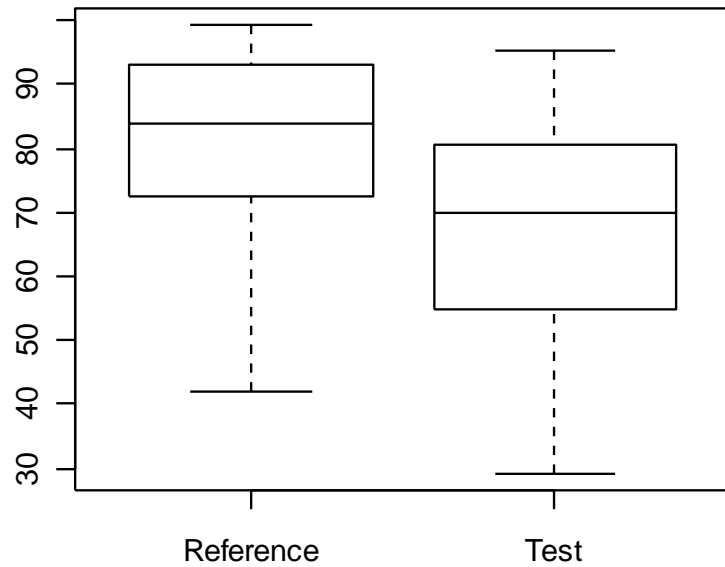- Redundancy

Discrimination Efficiency

$$DE = 100 \times (a / b)$$

a = the number of degraded samples scoring below the 25th percentile or above the 75th percentile of the reference
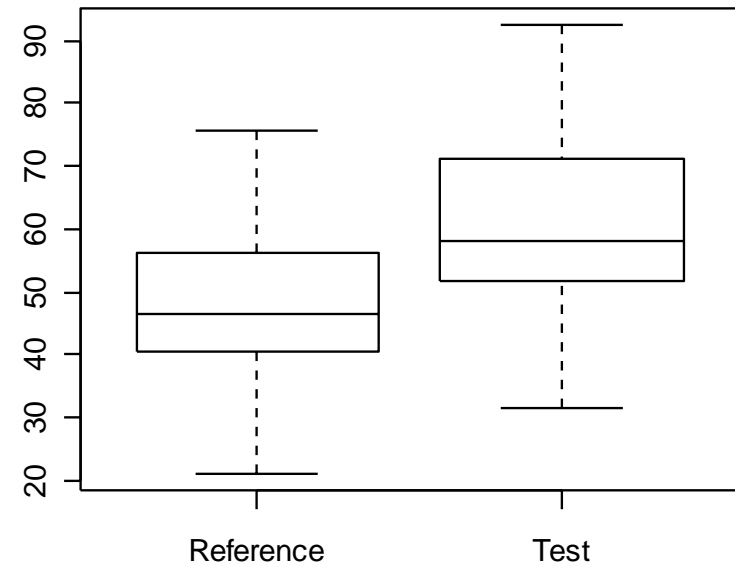
b = the total number of degraded samples

(Stribling et al. 2000)

Composition Metrics	Predicted Response to Stress	DE -	DE +
% EPT	-	48.78	
% Ephemeroptera	-	41.46	
% Plecoptera	-	36.59	
% Trichoptera	-	14.63	
% Diptera	+		68.29
% Diptera non-chironomidae	+		45.61
% Oligochaeta	+/-	14.63	17.07
%Baetidae	+		21.95
%Chironomidae	+		63.41
%Ephemerellidae	+/-	53.66	17.07
%Heptageniidae	unkn	41.46	7.32
%Hydropsychidae	+		36.59
%Nemouridae	unkn	34.15	14.63
%Rhyacophilidae	unkn	34.14	17.07
% Non-insect	+		17.07
EPT /Chironomidae	-	68.30	
Hydropsychidae / Trichoptera	+		41.46
Baetidae / Ephemeroptera	+		29.27

n = 27

Metric Selection Criteria

- Range of values
- Percent of values greater than zero
- Respond as predicted
- Discrimination Efficiency
- **Redundancy**

Metrics	Pearson Correlations > 0.8
EPT /Chironomidae	% Diptera (-.923)
EPT /Chironomidae	%Chironomidae (-.947)
% Scrappers + Shredders	%Heptageniidae (.808)
% Scrappers + Shredders	% Collector (-.885)
% Scrappers + Shredders	% Scrapper (.934)
Collector Richness	Collector-Gatherer Richness (.939)
Biologic Community Index	% EPT (-.815)
Biologic Community Index	Hilsenhoff Biotic Index (HBI) (.882)
% Univoltine	% Multivoltine (-.989)
% Univoltine	% Semi and Univoltine (.992)
% Univoltine	Intolerant % (< EPA TV3) (.850)
% Intolerant Ephermeroptera	%Ephemerellidae (.894)
Intolerant % (< EPA TV2)	Hilsenhoff Biotic Index (-.916)
Intolerant % (< EPA TV2)	Intolerant % (< EPA TV3) (.911)

n = 14

Multimetric Index Development

- Identification and definition of candidate metrics
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Metric Calibration Formulas

Metric	Scoring Formula	Critical scoring values	
		5th%ile	95th%ile
Diptera Richness	100*(9-metric)/(9- 5th%ile)	1.65	
% EPT	100*metric/95th%ile		98.07
% Ephemeroptera	100*metric/95th%ile		87.02
% Plecoptera	100*metric/95th%ile		32.39
%Heptageniidae	100*metric/95th%ile		50.42
EPT /Chironomidae	100*metric/95th%ile		2.3939
% Scrappers + Shredders	100*metric/95th%ile		62.8
Collector Richness	100*(16-metric)/(16-5th%ile)	5	
Biologic Community Index	100*(75.65-metric)/(75.65-5th%ile)	30.5	
Fine Sediment Biotic Index	100*metric/95th%ile		5.34
% Univoltine	100*metric/95th%ile		92.3
% Intolerant Ephermeroptera	100*metric/95th%ile		37.06
Intolerant % (< EPA TV2)	100*metric/95th%ile		78.02
Intolerant Richness (bi)	100*metric/95th%ile		13.35

Multimetric Index Development

- Identification and definition of candidate metrics
- Metric Selection
- Metric Calibration

• Compilation of the NCIBI

- Assessment of NCIBI

Candidate Index Configurations

Metric	Trial			
	1	2	3	4
Diptera Richness	X	X	X	X
% EPT		X		
% Ephemeroptera	X		X	X
% Plecoptera	X	X	X	X
% Heptageniidae			X	
EPT / Midge	X	X	X	X
% Scrappers + Shredders	X	X		X
Collector Richness	X	X	X	X
Biotic Condition Index	X	X	X	X
Fine Sediment Biotic Index	X	X	X	
% Univoltine	X	X	X	X
% Intolerant Ephemeroptera	X	X	X	X
% Intolerant (TV2)	X	X	X	X
Intolerant Richness	X	X	X	X
Total Number of Metrics	**12**	**12**	**12**	**11**

NCIBI = 11 Metrics from 5 Groups

Composition ⟶ **% Ephemeroptera**
% Plecoptera
EPT / Chironomidae

Functional ⟶ **% Scrappers & Shredders**
Feeding Group
Collector Richness

Biotic Index ⟶ **Biotic Condition Index**

Voltanism ⟶ **% Univoltine**

Indicator ⟶ **% Intolerant Ephemeroptera**
Assemblage
% Intolerant (TV2)
Intolerant Richness